WORKSHOP ON PROSPECTS FOR U.S.-P.R.C. COOPERATION ON EARTHQUAKE ENGINEERING RESEARCH

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U.S. Panel on the Evaluation of the U.S.-P.R.C.
Earthquake Engineering Program

Commission on Engineering and Technical Systems
National Research Council

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Introduction: U.S.-P.R.C. Protocol for Scientific and Technical Cooperation: Annex III

In January 1980, the United States of America (U.S.) National Science Foundation and U. S. Geological Survey together with the Peoples' Republic of China (hereafter, P.R.C. or China) State Seismological Bureau and the State Capital Construction Commission established a joint protocol for scientific and technical cooperation in earthquake studies. The U.S.-P.R.C. Protocol for Scientific and Technical Cooperation (hereafter, The Protocol) was the outgrowth of a series of delegation exchanges between 1976 and 1979. The rationale for the establishment of a protocol was the realization that the United States and China are among the countries most threatened by earthquakes and the recognition of value to be gained from an exchange of information from the serious research and mitigation programs in operation in each country.

The Protocol includes seven annexes, the titles of which are listed in Appendix A. Annex III of The Protocol is *Cooperation in Earthquake Studies: Cooperative Research on Earthquake Engineering and Hazards Mitigation.* The primary objective of Annex III is the development of safe and cost-effective engineering design methods and construction practices and other countermeasures to improve seismic safety. Initially the emphasis of this Annex was on the application of engineering knowledge of earthquake strong-ground motion, its effects on structures, and the dynamic behavior of soils. Recently, in their cooperative discussions concerning this Annex, both the United States and China have included other aspects of earthquake reduction, such as mitigation measures, emergency management, social and economic effects, and education.

Primary responsibility for the administration of Annex III lies with the Division of Biological and Critical Systems within the Engineering Directorate of the National Science Foundation (NSF) in the United States and with Office of Earthquake Resistance within the Ministry of Construction (MOC) in China. Representatives of the NSF Engineering Directorate and the MOC Office of Earthquake Resistance meet annually to review the status of joint work being conducted under The Protocol and to set the agenda for future cooperative efforts.

In 1989 NSF and the MOC agreed that much benefit could be derived from a joint U.S.-P.R.C. workshop that would bring together experts from both countries to identify the research strengths of each country and define a joint research agenda for consideration under Annex III of The Protocol. The workshop, which was hosted by the P.R.C. Institute of Engineering Mechanics of the State Seismological Bureau, was held in Guangzhou, China, on April 25–28, 1992.

Focus and Purpose of the Joint Workshop

In conducting this 1992 joint U.S.-P.R.C. workshop, the National Research Council (NRC), in cooperation with the P.R.C. Institute of Engineering Mechanics (IEM) of the State Seismological Bureau (SSB), responded to a National Science Foundation request to develop a plan for a coordinated program that could be used to assist the NSF program officers responsible for carrying out activities under Annex III of The Protocol. Activities normally conducted under Annex III include exchange programs of engineers, scientists, and other related experts; exchange of scientific and technical information; conduct of cooperative research programs; and joint organization of scientific conferences, symposia, and lectures.

The joint workshop had five primary goals, including the identification of

1. U.S. and P.R.C. organizations and individuals to participate in future activities;
2. ways to enhance technical effectiveness and cooperation of the program;
3. examples of successful joint research programs;
4. specific areas of mutual interest and benefit for future cooperative activities; and
5. ways to improve the management of the program.

To accomplish its task, the NRC appointed an eight-member delegation of experts in earthquake engineering, engineering seismology, structural engineering, geotechnical engineering, and disaster planning and preparedness. The IEM assembled a delegation with similar expertise.

The workshop consisted of 20 prepared presentations followed by group and executive session discussions. A complete list of names of the U.S. and P.R.C. delegates and the topics of their presentations is included in Appendix B. This report of the workshop includes the following sections: (1) a summary of the research environment in each country; (2) an outline of the operational environment of each country, including brief descriptions of the responsible agencies; (3) a discussion of the models of cooperation that could be applied to the program; (4) a brief summary of several successful cooperative programs; (5) a detailed discussion of possible areas of future cooperation; and (6) a proposed list of principles to be applied in the prioritization of projects to be selected for funding under the protocol.

Nature of the Research Environment

Damaging earthquakes occur relatively frequently in China and in the United States. In China the 1974 Haicheng Earthquake and the 1976 Tangshan Earthquake were disastrous events. Since then, numerous strong earthquakes have occurred in China, though fortunately not close to any major cities. The 1989 Loma Prieta Earthquake in the United States caused an estimated $6 billion to $10 billion of losses and would have been much more damaging had the earthquake been centered closer to the city of San Francisco. Participants at this joint workshop briefly reviewed the history of the occurrence of strong earthquakes and the research being carried out on earthquake hazard reduction. They discussed the active seismicity and the general research environment in the two countries and agreed that opportunities existed for research that could be more productive if carried out cooperatively rather than solely in one country. The follow summary of the research environment served as the basis for development of the potential areas for Annex III funded research discussed in the *Opportunities for Future Cooperation* section of this report.

RESEARCH ENVIRONMENT IN CHINA

Seismicity of China

China is one of the most seismically active regions in the world. There have been more than 200 earthquakes with magnitudes greater than M6.0* in China since 1900. Seven of these earthquakes have had magnitudes greater than M8.0, a level of seismic activity much higher than in the United States. The largest earthquakes in China generally occur in one of five well-defined zones. Seismic activity in China also appears to occur in cycles with two predominant periods, 200 to 300 years and 10 to 20 years. This cyclic pattern is seen in the temporal reoccurrence of earthquakes as well as their spacial variation.

Many seismologists believe that China has undergone four cycles since 1895, with the last active stage lasting from approximately 1966 until the great 1976 Tangshan Earthquake. From 1976 to 1985 there was a relatively quiescent stage with little activity. The 1985 M7.4 Wuqia, Xinjiang Earthquake is believed by some to mark the beginning of a transitional stage of activity. In 1988 the M7.6 and 7.2 earthquakes in Lancang and Gengma reflected a continuation of this stage.

* Throughout this report, M is used to designate earthquake magnitude as measured on the Richter scale.

If history is an accurate gauge, China could enter a new period of high seismic activity in the 1990s. This active stage would probably last for approximately ten to twenty years and be associated with the occurrence of ten or more strong earthquakes with magnitudes greater than M7.0. Such a strong activity level could provide an opportunity for studying earthquake mechanisms, local-site effects, and the response of structures. The relatively high Q value for China means that seismic motions are felt at great distances from the epicenter, thus increasing the likelihood of recording significant motions from a given event.

Advancements in Earthquake-Resistant Construction

China has under way a major construction program including housing, industrial facilities, office buildings, and infrastructure of cities. Providing adequate seismic resistance at affordable cost is an important aspect of that program. Research addressing engineering seismic hazard assessment, provision of appropriate seismic resistance of structures, and the balance of cost versus risk could provide results of use to both countries, especially from research on special structures commonly used in both China and the United States.

Major Rehabilitation Projects

Improved understanding of earthquake engineering now indicates that many of the existing important structures in China (as well as in the United States) may be deficient in seismic resistance. The strengthening of such weak structures is an important element of disaster mitigation. Investigations of these structural deficiencies and development of plans for their rehabilitation could provide data of use to both countries.

Experimental Field Studies

The recording of strong-ground motions and the recording of earthquake response of special structures would provide data of use to researchers both the United States and China. In recent years China has initiated a vigorous program of construction of high-rise buildings, dams, offshore platforms, power plants, etc. This new construction program offers the possibility to plan and install experimental research equipment as the new facility is being designed and built. Such a program could provide valuable data to both countries.

In addition, existing special structures, such as large concrete and earth dams, long-span bridges, nuclear power plants, high-rise buildings with more than twenty stories, offshore drilling platforms, and TV towers, as well as soil structures and soil deposits, offer an opportunity for data collection through field investigations of the dynamic properties of such structures.

Experienced Researchers

The availability of experienced researchers is key to the success of any cooperative research program. The government of China has recognized the importance of earthquake engineering research for minimizing the impact of future earthquake disasters. China has a number of government research laboratories as well as experienced researchers working in earthquake engineering at a considerable number of universities. Identification of appropriate researchers in the two countries and the ability to arrive at a satisfactory agreement on a project are important preliminaries to establishing research activities. Practically every research topic of interest to U. S. researchers will probably be of interest to P.R.C. researchers.

Exchange of Data on Earthquakes and Natural Disasters

Earthquakes and other natural disasters that occur relatively frequently in China can provide data that could be of use to the United States. Chinese language reports that describe disasters such as the Tangshan Earthquake should be translated into English and disseminated because valuable lessons can be learned by city, state, and national government agencies regarding the nature of the disasters, the response, and the recovery.

Availability of Qualified Technicians

The number of qualified technicians available for the support of earthquake engineering research is much greater in China than in the United States. For this reason, cooperative programs that are carried out in China have the advantage of excellent technical support. This is especially important for experimental research and field research.

Availability of Special Equipment

Many government and university laboratories in China are equipped for structural and soil testing. These laboratories are staffed by highly trained individuals, have state-of-the-art equipment, and can be very useful for some cooperative research. An example is the set of four rotating mass shaking machines designed and built by the Ministry of Water Resources, Institute of Water Conservancy and Hydroelectric Power Research (IWHR) in Beijing. These units, which exceed the capacities of any such units in the United States, can be synchronized to apply horizontal harmonic test forces up to about one ton each over a range of frequencies. They are used for field measurement of the vibration mode shapes and frequencies of very large structures such as concrete or earth dams and large multistory buildings. They have already been used for the study of two large concrete arch dams in China in a cooperative project described in the section on *Representative Examples of*

Successful Cooperation, Earthquake Performance of Concrete Arch Dams.

The IWHR has a six degree of freedom, 5 meter by 5 meter shaking table with a 20 ton capacity and 1 g maximum acceleration. Tonji University has a six degree of freedom 4 meter by 4 meter shaking table with a 15 ton capacity and a 1.2 g maximum acceleration. The China Academy of Building Research has a 12 meter by 14 meter reaction wall for testing nearly full size structures, a 10 meter by 8 meter reaction wall with pseudo-dynamic test capabilities, and a unidirectional 3 meter by 3 meter shaking table. All of these shaking tables are designed for testing small scale models of structures.

RESEARCH ENVIRONMENT IN THE UNITED STATES

Computer Hardware and Software

The amount and level of sophistication of computer hardware and software applicable to earthquake engineering research and the availability of computers and software is an important element in almost any earthquake engineering research program. Much of the available U.S. computer software could be used to advantage in China. Very large computers available within the United States could be used in projects requiring large-scale computation.

Experienced Researchers

Access to the large number of experienced U.S. researchers in earthquake engineering could offer opportunities for the transfer of experience to China. Areas of U.S. expertise include seismic instrumentation, seismic data, computational analyses, structural behavior, properties of structural elements, geotechnical engineering, and soil liquefaction as well as structural engineers experienced in the design of structures to resist earthquakes.

Special Facilities and Equipment

Cooperative use of special U. S. facilities and equipment that complement those available in China could provide benefits to both countries. For example, there are several large U.S. centrifuges that are especially useful for studying the dynamics of earth structures, such as earth dams, under vibratory conditions. The development of a joint research project that could make use of such facilities could result in a valuable exchange of information.

University Research Programs

Currently the United States has more earthquake engineering research programs in its universities than do P.R.C. universities. Interactions in the forms of exchange programs for both people and information could provide a strong base for researchers from China to learn from ongoing U.S. activities.

Availability of Information

In China theoretical knowledge of earthquake resistant design is quite advanced, and practical applications are expanding. A program of increased dissemination of the large quantity of information and data readily available in the United States, including materials in earthquake engineering libraries, strong-motion data repositories, journals, and reports, could make available a large body of historical information to P.R.C. researchers.

Nature of the Operational Environment

In addition to the two government agencies responsible for Annex III (P.R.C. MOC and U.S. NSF), there are within each country a number of other government agencies that provide varying levels of funding in support of earthquake engineering activities. Workshop participants discussed several of these agencies as well as identifying many of the universities and other research laboratories involved in research in both countries. Following are brief descriptions from several major P.R.C. and U.S. agencies, outlining the focus of their operation.

ORGANIZATIONS WITHIN CHINA

Ministry of Construction (MOC)
Office of Earthquake Resistance (OER)

Established in March 1967, the Office of Earthquake Resistance of the P.R.C. Ministry of Construction is a professional administrative department responsible for earthquake resistance and disaster prevention throughout China. Earthquake resistance is important for city planning, urban and rural area construction, the real estate industry, and investigation, design, construction and supervision in the construction industry. The MOC is concerned with earthquake emergency response, technical code and standards, development of international cooperation, and education and training in earthquake engineering.

Proposals by researchers for OER funding are subjected to a peer review. The types of projects funded by the OER include:

- countermeasures to mitigate earthquake disasters in cities and technical research for earthquake resistance and disaster prevention;
- earthquake resistance research and test technologies for building and engineering structures;
- seismic behavior research for special works, structures, and equipment;
- foundational technology and theory on earthquake engineering, including strong earthquake observation and earthquake mitigation and control technology.

State Seismological Bureau (SSB)

Established in August 1971, the P.R.C. State Seismological Bureau is responsible for the central management and administration of earthquake monitoring, prediction, and scientific and engineering research for the entire P.R.C. The Institute of Engineering Mechanics, a unit of the SSB located in Harbin, plays a key role in earthquake engineering research at the government level. SSB formulates policies and programs; plans projects related to national seismological work; allocates personnel, funds, and materials; and conducts

international cooperation and exchange programs in earthquake studies. The SSB also has done and is doing extensive field studies of societal responses to earthquake hazards and events and includes a formal subsection which focuses specifically on seismosociology. Appendix C is a summary of the organization and research foci of the SSB.

National Natural Science Foundation of China (NNSFC), Department of Architectural Environment and Structural Engineering

Established in 1986, the NNSFC promotes basic research and some applied research and is charged with the responsibility of working to institute a science funding system within China. A percentage of the total NNSFC budget is allocated to support international joint research and exchange projects.

The NNSFC funds research in four project categories. For each category, applications are evaluated and awards made annually. Any qualifying scientist or technological worker [engineer] may apply for any of the awards. The evaluation system for project selection is a strict, expert evaluation system, consisting of 58 proposal panels with 685 evaluation specialists of high academic level and more than 20,000 correspondence evaluation experts.

1. *Free application projects:* Approximately 60 percent of the annual NNSFC budget is used to support "free application" projects. Scientific and technological workers from different departments, regions, and institutions throughout China apply for support according to prescribed procedures.
2. *Projects for young scientists:* Applicants for funding under this program must be under 35 years of age and hold a doctoral degree.
3. *Projects for developing regions:* These funds are used to support scientific researchers in the universities and colleges and research institutes of remote areas or regions where minority nationalities live and scientific bases are weak.
4. *Projects for exploring new ideas and concepts in the field of high technology:* Approximately two percent of the total budget is used to support projects for exploring new ideas and concepts. The application guidelines for this funding are followed in accordance with the P.R.C. "Outline for Development of High Technology Research," and the evaluation procedure is the same as for the other three categories of projects.

Within the NNSFC, the Department of Architectural Environment and Structural Engineering supports research in basic theory, technical advances, and earthquake hazard mitigation. Examples of research areas in which the department has funded projects in the past four years include (1) hazard assessment of foundation, site, and earthquake; (2) soil-structure interaction under the input of earthquake waves; (3) structural dynamic responses under action of earthquake waves; (4) earthquake resistant studies on lifeline engineering, (5) studies on base isolation and structural control; and (6) studies on earthquake site investigation and aseismic experimental technology.

State Education Commission (SEC)

The State Education Commission are responsible for funding research in universities. The funds are primarily for fundamental or basic research, with some available for important applied research. There are four types of funding available for the faculties of the universities belonging to the State Education Commission.

1. *Regular research funds.* Funds are distributed annually to universities which are responsible for their administration. Faculties can apply for and funds will be granted when the proposal is approved by the university.
2. *Research funds for doctoral education.* Professors qualified as advisors of graduate students pursuing doctoral degrees are eligible to apply for these funds. Proposals are reviewed and approved by the SEC based on the results of peer review.
3. *Funds for young researchers.* The mechanism of approval of applications for these funds is similar to that of research funds for doctoral education.
4. *Special funds.* These funds are available for programs with major scientific or practical significance. Applications are reviewed and approved by the SEC.

Ministry of Energy
Science and Technique Development Foundation of Power Industry (STDFP)

Before 1989 the Science and Technique Department of the Ministry of Water Conservancy and Electric Power Industry was responsible for funding important applied and basic research projects in the related fields of water conservancy and electric power. Only organizations related to the Ministry could apply for funding. Proposals for theoretical and analytical investigations as well as laboratory and field tests were reviewed and approved individually by the department, based on the results of peer review. Usually priority was given to international joint research and exchange projects.

After the reorganization of the Ministries in China in 1989, a Science and Technique Development Foundation of Power Industry (STDFP) was established by the China Association of Power Enterprises affiliated with the Ministry of Energy. A special committee with three subcommittees (hydroelectric, thermoelectric, and electric systems) is now responsible for the funding decisions.

The STDFP is geared to the power industry throughout China. Under this new arrangement, any research institute, university, design, or production organization, as well as qualified scientists and technological workers, may apply for the awards in accordance with annual guidelines. Each applicant must be reviewed by two high-level academic experts and will be selected through a strict expert-evaluation system.

P.R.C. Universities and Other Research Laboratories

Appendix E lists major research universities and laboratories in China that work in fields related to earthquake engineering.

ORGANIZATIONS WITHIN THE UNITED STATES

In 1977, the U. S. Congress passed the Earthquake Act, which provided a national focus for the U.S. earthquake hazards research program by establishing the National Earthquake Hazard Reduction Program (NEHRP). Through this act, Congress charged the NEHRP with the following:

- conduct earthquake hazard-identification and vulnerability analyses;
- develop seismic design and construction standards;
- develop an earthquake prediction capability;
- prepare plans for mitigation, preparedness, and response activities;
- conduct fundamental and applied research into the causes and implications of earthquake hazards; and
- educate the public about earthquake hazards.

Four federal agencies are specifically authorized as principal agencies under the NEHRP. The following is a list of those agencies and a brief description of their involvement in earthquake engineering and other hazards mitigation activities. A summary of their program responsibilities and foci is included in Appendix D.

Federal Emergency Management Agency (FEMA)

As lead agency for the NEHRP, FEMA has primary responsibility for translating the research programs of the other agencies into effective earthquake hazard-reduction measures at the state and local levels. FEMA's program includes assistance in (1) implementation of comprehensive earthquake hazard-reduction measures, (2) development and application of construction techniques and standards, (3) development of public education and awareness programs, and (4) coordination of the federal response to catastrophic earthquakes.

FEMA provides funding principally to state and local governments in support of their earthquake mitigation and preparedness planning efforts. Among the key groups they support are the State of California Earthquake Program and the Central United States Earthquake Consortium.

National Science Foundation (NSF)

The focus of the NSF is fundamental research necessary to meet the NEHRP objectives. In the area of earthquake engineering, NSF supports programs in siting and geotechnical systems, structural systems, architectural and mechanical systems, and earthquake systems integration. In the area of earth sciences, NSF programs include research on earthquake mechanisms, crustal movements, and seismology.

The NSF makes awards to universities and other organizations throughout the country. Proposals for funding are evaluated through peer review. Support is provided for research, the training of students, and information dissemination. In addition to single investigators, the NSF supports two earthquake research centers: the National Center for Earthquake Engineering Research at the State University of New York, Buffalo, and the Southern California Earthquake Center (with support from U. S. Geological Survey) at the University of Southern California.

U.S. Geological Survey (USGS)

The responsibilities of the USGS include (1) identification and evaluation of potentially seismic areas, (2) development of prediction methods, (3) distribution of data and information on earthquake occurrences to the public and scientific communities, (4) assessment of earthquake hazards and risk in urban regions, and (5) production of data and estimates of the level and character of strong-ground motion for earthquake-resistant design and construction.

The USGS has both an intramural (with its large staff) and extramural research program. The external research program is geared toward providing funds for university and other investigators. Along with NSF, USGS has been a major supporter of the Southern California Earthquake Center. The USGS has the largest budget in the NEHRP.

National Institute of Standards and Technology (NIST)

As the nation's physical sciences and engineering measurement laboratory, NIST provides technical support and conducts research for developing, testing, and improving seismic design and construction methods. It also provides technical guidance on incorporating these provisions into federal construction practices, national standards, and state and local regulations. NIST uses its modest earthquake funds to support the work of its own staff, which includes laboratory research. NIST also receives funds from FEMA to carry out joint activities related to building codes and standards.

Other U.S. Government Agencies

Several other U.S. agencies are also concerned with and provide support for various types of earthquake engineering research and application. These agencies include (1) the U.S. Bureau of Reclamation in the Department of Interior, (2) the Nuclear Regulatory Commission, (2) the Department of Energy, (3) the Corps of Engineers of the Department of the Army, and (5) the Department of Transportation.

U:S. Universities and Other Research Laboratories

Appendix F lists major research universities and laboratories in the United States that work in fields related to earthquake engineering.

Models of Cooperation

A major goal of the U.S.-P.R.C. Protocol is to promote the development and exchange of knowledge between two of the most earthquake-prone countries in the world. Workshop participants agreed that it is incumbent on the members of the technical community in each country to take advantage of as many opportunities and to use as many methods of cooperation as possible. For any cooperative program to add long-term value to the discipline, the program must encourage both formal and informal mechanisms that will widen the community of researchers participating in the process and increase the dissemination of research results. In the areas of Annex III research, NSF and the MOC should take the lead in encouraging cooperation on all levels.

Three primary mechanism were suggested by workshop participants that could assist in the accomplishment of this goal.

1. Bringing together potential co-researchers from China and the United States for the purpose of generating future cooperative research projects.
2. Promotion of the Annex III mission to researchers and participation of researchers in refinement of the mission in the subsequent international discussions.
3. Presentation of the results of the studies to the professional communities.

MECHANISMS FOR BRINGING PEOPLE TOGETHER

At an informal level, there are in China and in the United States researchers who know each other and have, in some instances, conducted joint research projects. Individuals who possess these international contacts could be strongly encouraged to increase their number and to involve others and promote informal introductions whenever deemed appropriate.

At the next level, workshops on definite topics could be arranged for a mix of researchers from China and the United States. Invitations could be structured to ensure that people of various ages, affiliations, and experience from each country are included. It would be inappropriate if only senior researchers and principals attended those workshops.

Finally, on the most formal or structured level, established professional organizations could be encouraged to provide a forum for exposing their memberships to the work and opportunities that can occur through the P.R.C.-U.S. Protocol Annex. Papers, announcements, and addresses made to those professional groups should welcome new people to the cooperation. For example, the Earthquake Engineering Research Institute, the International Association of Earthquake Engineering, and others could be encouraged to expand the scope of their meetings and newsletters to include coverage of the U.S.-P.R.C. Annex III activities, and mechanisms could be developed to ensure that various professional groups interested in seismic engineering are more systematically exposed to the program.

MECHANISMS FOR COORDINATION AND REVIEW OF ANNEX III RESEARCH

Since the signing of The Protocol in 1980, the U.S. National Science Foundation and the P.R.C. Ministry of Construction have held annual working meetings for the coordination of Annex III. In addition to the respective governmental delegates, each side has, on an ad-hoc basis, invited researchers to discuss ongoing or possible future cooperative research programs. Workshop participants suggested that the shortcomings of this ad hoc selection process appear to be (1) discontinuity of the advice provided by the researchers and (2) a lack of formal feedback about opportunities for cooperative U.S.-P.R.C. research participation from these researchers to the research community at large.

To provide more formal structure, participants suggested that representatives responsible for Annex III consider a system whereby three researchers from each country would be formally appointed as delegates to these annual coordination working meetings. Each researcher would serve for three years, with staggered term-end dates. In accepting appointments to this delegation, the researcher would be asked to assume the following responsibilities:

- attend each of the annual coordinating working meetings during the three-year term;
- assist the appropriate government agencies in identifying key research areas and potential researchers;
- act as a source of information for the research community at large on the U.S.-P.R.C. cooperative research program activities; and
- encourage active participation by established and new researchers in the research activities of the cooperative research program.

MECHANISMS FOR COMMUNICATION OF RESULTS

The communities of engineers, scientists, and others within the United States and China who are involved in the furtherance of research have access to numerous professional journals and publications, which regularly report on their activities. In addition, there exist a variety of professional and quasi-professional organizations that could be encouraged to assist in the dissemination of research results and in the education of the relevant communities on the wealth of resources and research opportunities offered through Annex III.

Representative Examples of Successful Cooperation

Participants at the workshop agreed that the U.S.-P.R.C. programs supported under Annex III have been responsible for major advances in the general knowledge base of earthquake engineering and have contributed to the Annex III objective of developing safe and cost-effective engineering design methods, construction practices, and other countermeasures for seismic safety. The following brief descriptions, prepared by workshop participants, describe four successful projects that have been funded through Annex III since 1980. (Names of the projects' principal investigators are shown in parentheses).

NETWORK/ARRAY PROJECTS

Cooperative P.R.C.-U.S. strong-motion network and array projects have been highly productive. The United States side has supplied modern accelerographs and technical assistance while the Chinese side has provided field maintenance, data processing, and archiving. Important earthquake data have been recorded that could not otherwise have been obtained. These data have been used in both the United States and China to achieve a better understanding of strong-ground motion and of the characteristics of strong-motion measuring instruments. Both sides have participated in the analysis of the data.

One network project involving the installation of strong-motion instruments in several potentially active regions of China was conducted by Tongji University (XU) and University of California at Berkeley (Bolt). Another project was jointly conducted by the Institute of Engineering Mechanics of China (Liu, Xie, and Peng), the California Institute of Technology (Iwan), the University of Southern California (Teng), and the U.S. Geological Survey (Boore). The latter project demonstrated the usefulness of the parking array concept in which an array of strong-motion instruments is temporarily deployed in a region of anticipated seismicity while awaiting deployment to other areas for measuring strong aftershocks or predicted mainshocks. A temporary deployment of this array in the Tangshan aftershock region yielded the greatest volume of data and the strongest multistation data yet recorded in China and provided the basis for refining the earthquake attenuation law for northern China. Data were also obtained to depths of 800 meters in mine shafts. This joint project yielded new insights into the nature of the long-period ground motion observed near a causative fault and the accuracy of analog and digital strong-motion measurements. Both of these projects were funded by the U.S. National Science Foundation with assistance from the U.S. Geological Survey.

EFFECTS OF INCOMPLETE SATURATION ON WAVE PROPAGATION AND LIQUEFACTION OF COHESIONLESS SOILS

This project, which was funded by the U.S. National Science Foundation, was a cooperative effort between The University of Michigan (Richart, Wood) and Zhejiang University,

Hangzhou, P.R.C. (Wu, Zheng). The primary objective of the project was to examine the effects of incomplete saturation of cohesionless soils on wave propagation. Research at the University of Michigan consisted primarily of laboratory investigations of capillary effects. Because of the availability of staff and equipment, the principal effort at Zhejiang University was on field studies of wave propagation. The field tests provided valuable data and led researchers to conclude that continued research is needed.

One major benefit of the project was the regular visits of responsible researchers from each country to the institutions of the other, resulting in the direct exchange of ideas about research and soil dynamics. Most of the visits included a series of lectures by the visiting professor, and several of the senior level researchers were able to spend extended periods, up to five months, visiting the facilities of the other.

EARTHQUAKE PERFORMANCE OF CONCRETE ARCH DAMS

One highly productive program of U.S.-P.R.C. cooperative research has been directed toward evaluation of the seismic safety of concrete arch dams. Sponsored by the National Science Foundation, Ministry of Construction, and Chinese Ministry of Water Resources, this project was initiated in the spring of 1981. The cooperating institutions were the IWHR of Beijing, the Tsinghua University of Beijing (Zhang), and the Earthquake Engineering Research Center of the University of California at Berkeley (Clough).

An essential step in such evaluations is the calculation of the vibration properties of the structure. In this program the validity of the mathematical model was demonstrated by comparison of the calculated results with those obtained by measurement on the structure. This research project was a valuable part of the U.S.-P.R.C. cooperative effort because each country was able to make a significant contribution: China provided the dam, most of the equipment, and the large team that carried out the field work, while the United States provided advice in the field work and conducted the computer analysis used for comparison.

The excellent results that were obtained in the study of the two dams demonstrated the validity of the proposed type of mathematical model. After completion of the studies, a workshop was held in Beijing to establish the state-of-practice in the earthquake response analysis of arch dams. One conclusion reached was that a major effort must be made toward development of procedures for measuring the reservoir bottom acoustic reflection coefficient, because this coefficient has a controlling influence on the magnitude of seismic stresses that may occur in the dam.

Accordingly, the first test of a new phase of the program was carried out on a concrete dam (Dongjiang Arch Dam) in Hunan Providence in September 1991. The cooperating institutions for this test were Quest Structures of Emeryville, California, (Ghanaat) and the IWHR of Beijing (Chen). The primary purpose of the field test was to measure hydrodynamic pressures; the acoustic reflection coefficients of the soil deposit at the bottom of the reservoir; and the dynamic interaction between the dam structure, reservoir, and foundation under actual field conditions using explosives to generate artificial ground motions. Data from the explosion tests are still being evaluated, but preliminary indications are that the test procedure was successful. However, because the dam was new, the test

reservoir contained little sediment and thus had a very high reflection coefficient. A major conclusion of the effort was that a second test of this type should be done at a dam where the reservoir has accumulated a lot of sediment so that a low bottom reflection coefficient can be expected. It is evident that the United States will benefit from the cooperative arrangement in such studies because of the environmental opposition to the use of explosion testing that has developed in the United States.

IMPROVEMENT OF SEISMIC DESIGN STANDARDS FOR BUILDINGS

Funded by the National Science Foundation, this project has developed reliability-based seismic design and analysis approach criteria for reinforced concrete buildings. Work on the project was conducted jointly by the Institute of Earthquake Engineering of the China Academy of Building Research (Wei) and Memphis State University (Hwang).

In this study, reliability-based seismic criteria in the load resistance factor design (LRFD) format were established for the design of reinforced concrete frame buildings. The proposed seismic LRFD criteria were applicable to three categories of buildings--ordinary, high risk, and essential--in various seismic zones. Furthermore, the proposed criteria could produce risk-consistent structures under various design conditions because seismic load factors and importance factors are determined for optimization.

Seismic load factors for ordinary buildings have been determined for various seismic zones in the United States. The seismic load factor for a high seismicity region is larger than the value for a low seismicity region. In current model building codes, a constant seismic load factor is used for all seismic zones, a policy that suggests a need for further investigation. The acceptable risk levels for high-risk and essential buildings are more stringent. To achieve such a performance goal, the importance factor is used to increase structural strength and stiffness. In this study, an importance factor of 1.2 is recommended for high-risk buildings and 1.5 for essential buildings. These values are consistent with those specified in the 1985 Uniform Building Code.

For a low seismicity area in which the design earthquake is less than or equal to 0.1 g, gravity loads rather than the seismic load dominate the design of ordinary and high-risk buildings. If the frame structure is designed only for dead and live loads and detailing of structural members follows the requirement specified in American Construction Institute code, then the frame structure has enough required seismic resistance. For essential buildings, a seismic design with both the seismic load factor and importance factor of 1.0 is required to achieve the acceptable risk level specified for essential building.

Opportunities for Future Cooperation

OVERALL MISSION OF ANNEX III

Participants at the Guangzhou workshop reviewed a number of specific recommendations for changes to Annex III that had been proposed by the U.S. and P.R.C. representatives at the 1991 meeting on Annex III of The Protocol. Workshop participants strongly supported the recommendation that the scope of the Annex be broadened beyond earthquake hazards to encourage "unified multiple-hazard approaches in research and mitigation.*" They believed that such an expanded focus could be effective in reducing life loss and property damage and is consistent with the goals of the United Nations International Decade of Natural Disaster Reduction Program.

Workshop participants also supported the representatives at the 1990 and 1991 meetings on Annex III in their view that the two countries should consider involving other government agencies on each side with jurisdiction in areas of seismic hazard reduction related to the Annex III activities. Participation of these agencies could be focused in research areas not directly covered by the other six annexes of The Protocol. Potential active candidate agencies identified at the 1991 Annex III meeting and endorsed by workshop participants included the National Natural Sciences Foundation of China and the State Seismological Bureau in the P.R.C. and the Federal Emergency Management Agency, United States Geological Survey, and the National Institute of Standards and Technology in the United States.

The benefits of such expanded government agency participation could include involvement of a broader base of researchers and practitioners; improved opportunities for accessing additional funding or co-funding sources; and broadening of the research perspectives, including an opportunity for expanding the Annex III focus to include multihazard applications not currently covered in other annexes.

RESEARCH AREAS FOR FUTURE COOPERATION

Workshop participants developed the following descriptions of potential areas for research under Annex III that they believed to be of the highest priority:

* Record of the Meeting of the Representatives of the National Science Foundation of the United States of America and the Ministry of Construction of the People's Republic of China under Annex III to the U.S./P.R.C. Protocol for Scientific and Technical Cooperation, November 2, 1991, Beijing, China.

Strong Ground Motion Studies

There are a number of factors that make cooperative U.S.-P.R.C. strong-motion projects particularly attractive. These include the greater occurrence of large earthquakes in China compared to the United States; the occurrence of earthquakes in China associated with a variety of fault types; and the high Q of China, which means that seismic motions are felt at great distances from the epicenter, thus increasing the likelihood of capturing ground motion from a given event.

In view of the anticipated onset of a new period of active seismicity in China, there is considerable advantage in undertaking strong-motion studies in China at this time. Much mutual benefit could be gained from the expanded deployment of strong ground motion instruments in China for the purpose of carrying out source-mechanism, wave-propagation, and local site effects studies. There is a very good chance of recording strong ground motion from an M7.0 or greater earthquake within 20 kilometers of the epicenter during the next several decades in one of the following regions: (1) the Xianshuihe fault between Daofu and Kangding, (2) near Wuqia in western Xinjiang Province, and (3) the Xiaguan-Dali region of western Hunan Province. Such measurements could be extremely valuable in understanding source and wave propagation effects.

Local site effects can be extremely important in influencing structural response as indicated in the Loma Prieta Earthquake. In order to adequately study local site effects, data must be obtained from three-dimensional arrays. Such arrays are costly to install and to operate. The benefits of international cooperation in the use of such arrays include increased likelihood of obtaining data, greater flexibility in site selection, and the sharing of resources. Cooperation between the United States and China on site effects research is particularly appropriate. Several sites in Yunnan and Sichuan provinces (including Lancang, Luxi, and Shangpan) appear to be ideally suited for the installation of three-dimensional arrays for the purpose of studying nonlinear local site effects such as soil liquefaction, earth cracking, and fault surface displacement. Possible sites for basin effects arrays may be found near the Red River fault zone or the Xianshuihe fault zone. The Tangshan region could also be suitable for a site effects experiment and could likely yield the earliest measurement of weak-motion data.

To be most useful, site effects studies must include the collection of relevant geotechnical data as well as the recording of both weak-ground and strong ground motion. Geotechnical data collection can be as expensive as the recording of strong ground motion. However, the expense can be justified by the importance of this data. Geotechnical data does not necessarily need to be obtained before ground motion records are obtained, although this may be useful. Geotechnical data collection would need to be the responsibility of China, with technical assistance provided by the United States.

The design of local site effects arrays should be undertaken in a manner consistent with the guidelines established by the International Experiment of the Effects of Surface Geology. This experiment is being conducted jointly by the International Association of Earthquake Engineering and the International Association of Seismology and Physics of the Earth's Interior. Test sites presently exist in Turkey Flat region of California and in the Ashigara Valley of Japan.

Response Measurement of Special Structures

Within China a number of special structures exist that are prime candidates for strong-motion instrumentation projects. These include nuclear power plants; major dams; modern high-rise buildings; offshore structures; liquid storage containers; and major lifeline structures such as bridges, surface transmission systems, underground transportation systems, buried pipelines, gas and electric distribution systems, water supply and sewage systems, and surface pipelines.

In the development of any cooperative structural response study, special attention must be given to the selection of candidate structures. One primary selection criterion should be the importance of the structure; a second should be the location of the structure in a region of relatively high seismicity; and a third should be its surroundings. Instrumentation projects that include similar structures in both the United States and China could be undertaken to increase the likelihood of obtaining data in a timely manner. These parallel projects should be viewed as a single, well-coordinated experiment. Additional benefits could be achieved by forming three-way projects with Japan or other countries.

Any cooperative structural instrumentation projects should include a formal agreement that could define how instrumented structures are to be selected, how dynamic analyses are to be carried out and results disseminated, how experimental studies are to be conducted and data obtained, and how this information is to be shared. Full-scale dynamic tests of instrumented structures should also be a part of any structural instrumentation program.

Evaluation and Strengthening of Structures

The inventories of structures vulnerable to the effects of natural hazards in China and United States are large and not likely to be totally replaced in the next few decades. Conducting a series of cooperative research efforts aimed at the management of this serious risk through the development of techniques for the identification, repair, rehabilitation, and strengthening of seismically vulnerable structures could be of great benefit to both societies. China could gain from the experience in the United States with retrofit programs (e.g., the building program of the city of Los Angeles and the bridge program of the California Department of Transportation) and from access to U.S. non-destructive evaluation hardware and software. The United States could gain from the active seismicity in China, the availability of qualified technicians to conduct laboratory and field work, and the extensive damage archives. A problem requiring fundamentally different methods for evaluation and remediation is that of retrofitting vulnerable construction in regions where the probability of occurrence of potentially destructive earthquakes is relatively small but not negligible.

Active and Passive Response Control

Passive control systems for civil engineering structures are becoming more common internationally as a means of reducing vibrations caused by winds and earthquakes. In addition, increased interest in active control of structural response has resulted from conceptual studies, theoretical analyses, and laboratory and field experiments and tests. Recently, prototype systems have been tested on full-size structures. Advantages of active, passive, or hybrid control systems, when used in some types of structures, can be demonstrated. There now exists a real opportunity for joint cooperative research to intensify these studies and verify their practical implementation for enhanced dynamic performance of buildings and bridges during strong winds or earthquakes.

Earthquake Hazard Mitigation Planning for Urban and Rural Areas

In almost all countries the actual implementation of most hazard and disaster planning is at the local community level, which can range from a village to a metropolitan area. This certainly is true of both China and the United States. Thus a general focus for cooperative research efforts on the social aspects of earthquakes could be through parallel projects on community earthquake hazard mitigation, preparedness, and response or recovery planning and managing. These research efforts could exemplify the influence of respective local conditions and practices. Similar types of communities subject to roughly the same seismic risks could be selected in each country and studied with a common research design. Data from both organizations and individual households should be obtained. While most of the work would necessarily have to be done in nonimpact situations, the opportunity for doing field studies during earthquake impact occasions should be built into the parallel or common research design.

In both the United States and China the existence of supercities with metropolitan populations of 5 million to 10 million inhabitants or more poses special problems. Beyond the immediate damage losses to structures and lifelines, an earthquake can have a profound and long-lasting effect on the functioning of the city. Severe damage to water, electricity, and gas supply systems; sewage systems; communication and transportation systems; and commercial and industrial functions can have a much greater, long-term impact on a supercity than on a small one. The appropriate level of seismic safety for a supercity is an issue that needs to be researched.

Prior to the formal initiation of any cooperative parallel research venture, a joint workshop could be held between P.R.C. and U.S. engineers, social scientists, economists, planners, public policy researchers, and other relevant participants. The focus of the meeting might be the theoretical and methodological approaches to hazard and disaster research that prevail in both counties, with a special emphasis on studies of the social aspects of mitigating, preparing for, responding to, and recovering from earthquakes. Such a workshop

could produce a state-of-the-art assessment of social science research in China and the United States, highlighting similarities and differences in empirical findings and research approaches, providing an opportunity for experts in each country to familiarize themselves directly with counterpart colleagues, and establishing agreed upon priorities for cooperative and common studies.

Hazard, Vulnerability, Risk Assessment for Important Structures

In both China and the United States, significant structures, such as dams, bridges, high-use buildings, offshore platforms, and nuclear power plant facilities, exist in or are planned for areas prone to seismic exposure. Damage or failure of these important structures could potentially mean extensive loss of life and property. Because of the high costs involved, safety of these structures against earthquake shocks is of great concern. Earthquake-resistant design standards (probability of exceedance stresses) are quite different in each country. In addition, for many of these construction sites there is a lack of historical data of seismicity.

Though sophisticated modeling and computation tools exist for computation of earthquake response, experience has indicated that different methods may lead to substantially different and sometimes contradictory results. Use of conservative upper-bound procedures has been found to increase construction costs without necessarily reducing the perceived uncertainties to a tolerable level. An additional problem is the inaccessibility of such procedures and computational tools to rank-and-file engineers who have to make the critical decisions about details of construction.

There is a need for simplified and effective methods for determining seismic vulnerability of important structures. In both the United States and the Peoples' Republic of China various attempts have been made toward development of simple technologies for vulnerability assessments. There is much to be gained for both sides from joint research projects to evaluate and improve the state of the art. A number of opportunities exist for joint research projects addressing the application of risk assessment analyses to important structures under Annex III.

Design Criteria for Important Engineered Structures

A structure such as a large dam, a long-span bridge, or an emergency-response facility may require special design criteria because of possible consequences of its failure. Although no nuclear power plants or offshore platforms have failed due to earthquakes, it is important to note that no large earthquake has yet occurred close to a nuclear facility. There are, however, examples of near-failure damage in several dams throughout the world. In 1962 the Hsingfengkiang Dam (height 105 meters) in China and in 1967 the Koyna Dam (height 103 meters) in India were overstressed by reservoir-induced earthquakes of magnitude higher than M6.0, and both concrete dams were damaged to an alarming degree. Near-failure damage also occurred to the Lower San Fernando Dam in the United States during the 1971 San Fernando Earthquake. Fortunately, the water level behind this 50 meter high earth dam was not at maximum level, otherwise it would most certainly have caused the

dam to fail, releasing the impounded water on the approximately 85,000 people living below. In 1925 the Sheffield earth dam did fail completely during the Santa Barbara Earthquake in California.

By the end of this century, the trend of the seismic activity in China is projected to increase. It is expected that a very large earthquake, M7.0 or even greater, may occur there in the near future. A number of large dams (concrete arch dams with the height of 250 to 300 meters and concrete gravity dams with the height of 200 meters) are being planned for construction in known high-seismic areas (earthquake intensity M7.0 or greater).

Cooperative research toward development of natural hazards design criteria for such structures, with researchers and practitioners in China and United States pooling their experience, could greatly facilitate the transfer of technology between the two countries and significantly improve the safety and the design criteria for the engineering of these structures.

Seismic Safety of Concrete Dams

In addition to the opportunities for future cooperation presented by continued use of explosion testing of concrete dam-reservoir systems (described in the section on *Representative Examples of Successful Cooperation, Earthquake Performance of Concrete Arch Dams*) the P.R.C. has several high-frequency shaking tables (see section on *Nature of Opportunities for Joint Research, Availability of Special Equipment)* that offer a unique opportunities for U.S. dam research workers. These tables can be used to validate computer programs for analysis of nonlinear response of concrete dams. The IWHR shaking table was designed specifically to carry out simulated earthquake tests on small-scale models of concrete dams and reservoir systems.

Linear elastic seismic safety analyses, which have been done of typical arch concrete dams, demonstrate that a severe earthquake can be expected to cause stresses that exceed the tensile strength of the concrete. Nonlinear programs are available to study the opening and closing of critical construction joints during seismic response. However, these analysis techniques need to be verified by model tests. Of even greater importance is the need to predict the degree of damage to concrete dams that could be expected during severe earthquakes. Mathematical models for damage mechanisms are much more difficult to develop than are joint opening models. It is essential to guide the development of such algorithms by physical experiment, especially if the analysis is intended to predict response up to and including collapse. And it is evident that testing of full-scale systems cannot be extended into the range of nonlinear responses; hence this IWHR facility will fill a major gap in present U.S. experimental test capabilities.

Post Earthquake Field Investigations

The occurrence of damaging earthquakes provides an excellent opportunity to learn directly from field observations of earthquake effects. Field investigations of the effects of ground

motion on structures, lifelines, infrastructure, and other constructed facilities, as well as the consequences of this damage on the social and economic operations of the effected area, province, and country, could contribute significantly to the existing knowledge base. Information obtained from these damaging earthquakes is best collected and analyzed by qualified professionals. To facilitate data collection, specific topics requiring field observations and agreements for cooperation should be established and a list of appropriate counterpart individuals and organizations should be developed prior to the occurrence of damaging earthquakes. Because many forms of earthquake data are perishable, quick action following a damaging event is essential.

Seismic Safety of Geotechnical Systems

Seismic safety of geotechnical systems, such as earth dams, retaining walls, and foundations, can be assessed by analytical procedures that have been verified by comparison with prior field measurements of the performance of full-scale (prototype) structures. In the absence of suitable field data, an alternative method of validation is possible by comparison with model tests conducted in a centrifuge in which the gravity effects are properly simulated.

The United States has recently brought into operation several centrifuges with earthquake simulation capabilities. Assistance could be given to develop similar capabilities on centrifuges in China. In the meantime, projects can be developed to take advantage of the U.S. capabilities to ascertain the accuracy of various procedures employed by P.R.C. geotechnical engineers in the design of earth structures. At the same time, projects should be developed in China for testing full-scale earth structures with induced seismicity (i.e., programmed explosions) and for simulating these events in U.S. centrifuges. Such cooperative research will enhance the understanding of the behavior of earth structures under dynamic loads and will lead to safer designs.

Principles Governing Prioritization

Participants at the workshop discussed the principles that they believed should be applied by both countries in the evaluation of research applications to be funded under Annex III. Proposals submitted under the U.S.-P.R.C. cooperative research agreement should describe clearly the goals of the research and contain a plan for the execution of the research as well as a plan for the dissemination of the results. They should be evaluated with the usual criteria for funding in the respective country. In addition, the following criteria should be applied in prioritizing these proposals for funding:

- the degree to which both countries will benefit from the results of the research;
- the qualifications and interest of the participants in the proposed research; and
- the degree to which the proposed project will capture unique opportunities, e.g., instrumentation of a new structure during construction.

In addition, ongoing projects that have demonstrated significant progress and which show future promise should be given priority consideration.

Appendix A:
Annexes of the Joint Protocol

Annex I: Cooperation in Earthquake Studies: Investigations of Premonitory Phenomena and Techniques for Earthquake Prediction

Annex II: Cooperation in Earthquake Studies: Investigations of Intraplate Active Faults and Earthquakes

Annex III: Cooperation in Earthquake Studies: Cooperative Research on Earthquake Engineering and Hazards Mitigation

Annex IV: Cooperation in Earthquake Studies: Cooperative Research Projects on Deep Crustal Structures

Annex V: Cooperation in Earthquake Studies: Cooperative Research Projects on Laboratory Studies in Rock Mechanics

Annex VI: Cooperation in Earthquake Studies: Deployment of Very Long Period Seismograph Stations (IDA) and Cooperative Research

Annex VII: Cooperation in Earthquake Studies: Exchange of Data and Films of Seismograms

Appendix B:
Participants and Presentation Topics for the Workshop on Prospects for P.R.C.-USA Cooperation on Earthquake Engineering Research

U.S. Participants and Presentations

Title: Recent Activities of the IAEE (International Association of Earthquake Engineering)
Presenter: **George W. Housner**, Professor Emeritus
California Institute of Technology

Title: Research Involving Strong Motion Arrays and Networks
Presenter: **Wilfred D. Iwan**, Professor of Engineering
California Institute of Technology

Title: Seismic Retrofit of Bridge Columns
Presenter: **Colin B. Brown**, Professor of Engineering
University of Washington

Title: Cooperative Research Program on Earthquake Performance of Concrete Dams
Presenter: **Ray W. Clough**, Professor of Engineering
University of California, Berkeley

Title: Evaluation of Seismic Safety of Earth Structures Through Analytical and Experimental Field Testing and Laboratory Model Studies
Presenter: **Hon-Yim Ko**, Professor of Engineering
University of Colorado

Title: Community Level Earthquake Planning and Response
Presenter: **E. L. Quarantelli**, Disaster Research Center
University of Delaware

Title: Experimental Analysis of the Earthquake Response of Reinforced Concrete Building Structures
Presenter: **Mete A. Sozen**, Professor of Engineering
University of Illinois

Title: The U.S. National Earthquake Hazards Reduction Program
Presenter: **William A. Anderson**, Head
Hazard Mitigation Section, National Science Foundation

Title: Active Members for Active Seismic Control
Presenter: **Robert D. Hanson**, Professor
University of Michigan

P.R.C. Participants and Presentations

Title: Ongoing Programs on Earthquake Disaster Mitigation in IEM
Presenter: **Xie Li-Li**, Professor and Director
Institute of Engineering Mechanics, SSB, Harbin

Title: Recommended Projects on Seismic Resistant Lifeline Engineering
Presenter: **Feng Qimin**, Professor and Deputy Director
Institute of Engineering Mechanics, SSB, Harbin

Title: Review and Prospects of the China-US Cooperation in Earthquake Studies on Large Dams
Presenter: **Chen Hou-qun**, Professor
Institute of Water Conservancy and Hydroelectric Power Research, Beijing

Title: Effect of Soil-Structure Interaction on Seismic Response of Important Structures
Presenter: **Lin Gao**, Professor
Dalian University of Technology, Dalian

Title: Prospects for the P.R.C./US Bilateral Mitigation and Earthquake Resistance of Engineering Structures
Presenter: **Cao Zi**, Professor
Beijing Polytechnic University, Beijing

Title: NSFC Supported Research Engineering Research Projects
Presenter: **Na Xiangqian**, Professor
National Natural Science Foundation of China, Beijing

Title: Comprehensive Disaster Prevention and Public Safety of Urban and Rural Society
Presenter: **Wang Ya-yong**, Associate Professor and Deputy Director
Institute of Earthquake Engineering, China Academy of Building Research, Beijing

Title: Perspective of the Cooperative Research on Active Control of Structures and Strong Ground Motion.

Presenter: **Xu Zhixin**, Professor
TongJi University, Shanghai

Title: Study on Dynamic Analysis of Tube-in-Tube Structures
Presenter: **Zhang Daming**, Research Professor
Seismological Bureau of Guangdong Province, Guangzhou

Papers distributed by the P.R.C. delegation which were not presented

Title: Prospects on Development of Intelligent Active Control and Vibration Absorbing Technology for Buildings
Presenter: **Wei Lian**, Professor and Director
Institute of Earthquake Engineering, China Academy of Building Research, Beijing

Title: On Hybrid Probabilistic Method of Seismic Hazard Analysis
Presenter: **Hu Yu-xian**, Professor
Institute of Geophysics, SSB, Beijing

Title: Advances and Prospects in Some Research Subjects on the Design Theory and Control of Aseismic Structures
Presenter: **Liu Ji**, Professor
Harbin Architectural and Civil Engineering Institute

Title: Earthquake Resistant Offshore Platform Structures
Presenter: **Chen Dan**, Professor
QingHua University, Beijing

Appendix C:
Program of the P.R.C. State Seismological Bureau

PROGRAM ACTIVITIES	RESPONSIBLE INSTITUTION	LOCATION
Study on solid geophysics, e.g., seismology, geomagnetism and deep structures, etc.	Institute of Geophysics	Beijing
Study on seismogeology, engineering seismology, lithosphere structure, and long, medium and short-term earthquake prediction	Institute of Geology	Beijing
Observation and study of crustal stress field	Institute of Crustal Dynamics	Beijing
Daily observation and prediction of nation-wide earthquake situation and management of the seismic data bank	Center for Analysis and Prediction	Beijing
Comprehensive observation and study on earthquakes in the northwestern part of China	Earthquake Research Institute	Lanzhou
Study on the theories and methods of geodesy and geodynamics	Institute of Seismology	Wuhan
Study on the theory of engineering seismology and earthquake engineering and their application	Institute of Engineering Mechanics	Harbin
Precise leveling and distant measurement in the eastern part of China	Geodetic Brigade	Tianjin
Leveling, geodetic survey, and gravity measurement in the western part of China	Second Geodetic Brigade	Xian
Mobile observation of precise leveling, gravity and geomagnetic measurement in Beijing region	Comprehensive Survey Brigade	Beijing
Exploration and study on crust and upper mantle structure and their distribution characteristics	Geophysical Prospecting Brigade	Zhengzhou

PROGRAM ACTIVITIES	RESPONSIBLE INSTITUTION	LOCATION
Education and training of the expertise on seismology	Seismo-technical College	Yanjiao Hebei
Compilation and publication of multi-discipline books relevant to earthquake studies	Seismological Press	Beijing
Recent development in earthquake study at home and abroad	Center of Seismological Information	Beijing

Appendix D:
U.S. National Earthquake Hazard Reduction Program

PROGRAM ELEMENTS	ACTIVITY	RESPONSIBLE AGENCY(S)
Earthquake Potential and Hazard Assessment	1. Earthquake Potential Assessments: Source Zone Characterization and Long-Term Forecasts	USGS
	2. Earthquake Hazard Assessments	USGS
Earthquake Prediction Research	1. Prediction Methodology	USGS
	2. Earthquake Prediction Experiments	USGS
	3. Theoretical, Laboratory, and Fault Zone Studies	USGS
	4. Induced Seismicity	USGS
Earthquake Engineering Research	1. Strong Ground-Motion Data Collection, Processing, and Analysis	USGS
	2. Siting and Geotechnical Engineering Research	NSF
	3. Structural Analysis and Design Research	NSF
	4. Computer Methods and Expert Systems Research	NSF
	5. Architectural and Nonstructural Components	NSF
	6. Research Facilities	NSF
	7. Research for Standards	NIST

PROGRAM ELEMENTS	ACTIVITY	RESPONSIBLE AGENCY(S)
Earthquake Planning and Mitigation	1. Development of Design Practices and Manuals	FEMA
	2. Federal Response Planning	FEMA
	3. State and Local Earthquake Hazard Reduction	FEMA
	4. Multihazard Planning	FEMA
	5. Insurance	FEMA
	6. Earthquake Systems Integration	NSF
Fundamental Earthquake Studies	1. Implications of Plate Tectonics	NSF
	2. Earthquake Processes	NSF
Information Systems and Dissemination	1. Engineering Information Services	NSF
	2. Seismologic Data and Information Services	USGS
	3. Education and Information Transfer	FEMA
Postearthquake Studies		FEMA/NSF/ USGS/NIST
International Cooperation	1. International Research	NSF/USGS/ FEMA/NIST
	2. International Decade for Natural Disaster Reduction	NSF/USGS/ FEMA/NIST

Appendix E:
P.R.C. Universities and Other Research Laboratories

Following is a list of major P.R.C. research institutions that conduct earthquake engineering research. The primary areas of research are identified by the following codes:

A - engineering seismology

B - strong motion instrumentation

C - performance of buildings

D - performance of dams

E - performance of bridges

F - geotechnical engineering

G - tsunami action

H - computational facilities available

I - experimental facilities available

J - performance of nuclear power plants

K - performance of industrial structures

L - societal response to natural disasters

M - structural response control

Beijing Institute of Architectural Design and Research **C**
62 Nan Li Shi Road
Beijing, 100045, China
Contact: Cheng, Maokun
Tel: 8012255-233 FAX: 8012255-209

Beijing Municipal Engineering Design Institute **E**
B. 2 Yuetan Nanjie
Beijing, China
Contact: Shen, Shijie
Tel: 862474

Beijing Real Estate Scientific and Technology Research Institute — **C**
Jin Song, Chao Yang District
Beijing, China
Contact: Lei, Tongshun
Tel: 5124112

Building Science Research Institute of Liaoning Province — **C**
88, Heping Southen Street
Shenyang, 110005, China
Contact: Lou, Yonglin
Tel: 361610

China Academy of Building Research Institute of Earthquake Engineering — **A, B, C, F, H, I, M**
Xiao Huangzhuang
An Wai, Beijing, 100013, China
Contact: Zhou, Xiyuan
Tel: 4214354 FAX: 86-1-4221369

China Academy of Railway Sciences — **E, F, H, I**
Department of Vibration and Aseismic Engineering
Railway Engineering Research Institute
Beijing 100081, China
Contact: Qian, Zheng
Tel: 8996837

China Northwest Building Design Institute — **C**
173 West 7th Road
Xi'an, Shanxi, China
Contact: Liu, Dahai
Tel: 715501

China Petro-Chemical Co. Earthquake Resistance and Vibration Research Center — **C, K***
P.O. Box 949
Beijing, China
Contact: Liang, Yu
Tel: 2017066-251 FAX: 2014932

China, College of **A, C**
Engineering Seismology Department Seismological Technical
Yan Jiao East of Beijing, China
Contact: XIE, Mosheng
Tel: 9546385

China National Petroleum Corporation, Research Institute of Engineering Technology of **C**
40 Jin Tang Road, Tanggu
Tianjin, 300451, China
Contact: Zhou, Xingshan
Tel: 983589 FAX: 987876

Communications, Ministry of **C, E**
Engineering Administration Department
10 Fuxing Road
Beijing, China
Contact: Li, Jingkui
Tel: 3260673 FAX: 3265544-2620

Construction, Ministry of **F**
Comprehensive Institute of Geotechnical Investigation and Surveying
177 Dong Zhimen Street
Beijing, China
Contact: Lin, Jie
Tel: 4013366-260 FAX: 4013189

Dalian University of Technology **C, D, E, H, I**
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Dalian, 116024, China
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Dalian University of Technology **C, D, F, H, I, J**
Earthquake Engineering Division
Dalian, 116024, China
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Guangdong Seismological Bureau **A, B, C**
81-Xianlie Zhong Road
Guangzhou, China
Contact: Zhang, Daming
Tel: 778583-274

Guangzhou Urban Construction Institute **C**
Lu Jing Road, Shan Yuanli
Guangzhou, China
Contact: Zhou, Fulin
Tel: (020) 663137 FAX: (020) 677315

Harbin Architectural and Civil Engineering Institute **C, H, I, J**
Harbin, China
Contact: Liu, Ji
Tel: 343512-422

Hehai University **D, H**
Research Institute of Water Resources and Hydroelectric Power
1 Xinkang Road
Nanjing, China
Contact: Chen, Hequn
Tel: 632106

Hehai University **D**
1 Xinkang Road
Nanjing, China
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Tel: 632106-931

Hua Chiao University **C**
Department of Civil Engineering
Quanzhou, Fujian, China
Contact: Wu, Bing
Tel: 24921

Machinery and Electronics Industries, Ministry of the **K**
Institute of Project Planning and Research
No. 277 Wangfujing Street
Beijing, China
Contact: Bao, Zhen
Tel: 558821-365 FAX: 5126675

Machinery and Electronics Industries, Ministry of the **K**
The Fourth Design and Research Institute
Luoyang, Henan, China
Contact: Shi, Bingsheng
Tel: 223001 FAX: 413310

Metallurgical Industry, Ministry of **C, F**
Research Institute of Disaster Reduction and Aseismic Engineering
Central Research Institute of Building and Construction
No. 43 Xue-Yuan Road
Beijing, 100088, China
Contact: Hou, Zhongliang
Tel: 2029897 FAX: 861-201-1361

Nuclear Industry, The Fifth Research and Design Institute of the **J**
96 Zhongyuan Road
Zhengzhou, Henan, China
Contact: Chen, Qibang
Tel: 448397

Nuclear Industry, The Fourth Research and Design Institute of the **J**
Shijiazhuang Hebei, China
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Nuclear Industry, Ministry of **J**
The Seventh Institute of Research and Project Planning
P.O. 130
Taiyuan, 030012, China
Contact: Zhang, Zhiheng
Tel: 772904-387

Seismological Bureau of Inner Mongolia **A**
Zhelimu Road
Huhhot, China
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Seismological Bureau of Jiangsu Province **A, B, C, D, E, F**
Institute of Earthquake Engineering
3 Weigang
Nanjing, China
Contact: Zhang, Xueliang
Tel: 432919

Shandong Building Scientific Research Institute **C**
13 Wuyingshan Road
Jinan, China
Contact: Liang, Bingqin
Tel: 556989

Shanghai Nuclear Engineering Research and Design Institute **J**
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Shanghai, China
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Tel: 4364700 FAX: (021) 4390846

Sichuan Seismological Bureau **A, B, C, D, F**
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Southeast University **C, H**
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Nanjing Jiangsu, China
Contact: Zhu, Jicheng
Tel: 634691

South-West Architectural Design Institute **C**
168 Jin Hua Street
Chengdu, China
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Tel: 32823

State Seismological Bureau **A, F, H**
Institute of Geology
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Beijing, 100029, China
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Tel: 2023377-278

State Seismological Bureau **A, B, C, D, E, F, H, I, J, K, L, M**
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11 Ying Zhe Xi Road
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1239 Siping Road
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Tel: 5455080-2666 FAX: 0086-021-5458965

Tongji University **A, B, C, E, H, I, J, M**
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Tsinghua University **C, F, H, I, J, M**
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Beijing, 100084, China
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Wuhan University of Technology **C, H, M**
Institute of Aseismic Engineering Structures
No. 14, Luoshi Road
Wuhan, 430070, China
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Tel: 713048-471

Zhengzhou Institute of Technology **C, D**
Department of Civil Engineering
97 Wenhua Road
Zhengzhou, China
Contact: Huo, Da
Tel: (037) 332113-404

Appendix F:
U.S. Universities and Other Research Laboratories

Following is a list of major U.S. research institutions that conduct earthquake engineering research. The primary areas of research are identified by the following codes:

A - engineering seismology

B - strong motion instrumentation

C - performance of buildings

D - performance of dams

E - performance of bridges

F - geotechnical engineering

G - tsunami action

H - computational facilities available

I - experimental facilities available

J - performance of nuclear power plants

K - performance of industrial structures

L - societal response to natural disasters

M - structural response control

Arizona, University of **C, E, H, I**
Department of Civil Engineering
Tuscon, Arizona 85721
Contact: Professor Mohammad R. Ehsani
Tel: (602) 621-6589 FAX: (602) 621-2550

Arkansas/Little Rock, University of **B, C**
Department of Electronics and Instrumentation
2801 South University Avenue
Little Rock, Arkansas 72204
Contact: Dr. James R. Blacklock
Tel: (501) 569-8000 FAX: (501) 569-8020

Army, U.S. Department of the **A, B, D, E, F, G, H, I, J, K**
Corps of Engineers
Waterways Experiment Station
Geotechnical Laboratory
3909 Halls Ferry Road
Vicksburg, Mississippi 39180-6199
Contact: Mr. W. F. Marcuson III
Tel: (601) 634-2234 FAX: (601) 634-3139

Brigham Young University **B, C, E, F, H**
Department of Civil Engineering
368 CB
Provo, Utah 84602
Contact: Dr. T. Leslie Youd
Tel: (801) 378-6327 FAX: (801) 378-2478

California Institute of Technology **A, B, C, D, E, F, G, H, I, J, K, M**
Department of Earthquake Engineering, Mail Code 104-44
Pasadena, California 91125
Contact: Dr. Wilfred D. Iwan
Tel: (818) 356-4144 FAX: (818) 568-2719

California Polytechnic State University **C, H, I**
School of Architecture and Environmental Design
San Luis Obispo, CA 93407
Contact: Dr. Paul R. Neel
Tel: (805) 756-1311 FAX: (805)756-5986

California, State of **C**
Office of the State Architect
400 P Street, 5th Floor
Sacramento, CA 95814
Contact: Mr. Harry C. Hallenbeck
Tel: (916) 322-4123 FAX: (916) 445-3521

California, State of **A, B, C, D, E**
Department of Conservation
Division of Mines and Geology
Office of Strong Motion Studies
801 "K" Street MS 13-35
Sacramento, CA 95814-3531
Contact: Mr. Anthony F. Shakal
Tel: (916) 322-3105 FAX: (916) 323-7778

California, State of **A, B, E, F, H, I**
Department of Transportation
Division of Structures
Office of Earthquake Engineering
P.O. Box 942874
Sacramento, CA 94274-0001
Contact: Mr. James H. Gates
Tel: (916) 445-1439 FAX: (916) 323-2259

California, University of **A, B, C, D, E, F, G, H, I, J, K**
Earthquake Engineering Research Center
Richmond Field Station
1301 South 46th Street
Richmond, CA 94804
Contact: Dr. Jack P. Moehle
Tel: (510) 231- 9554 FAX: (510) 231-9471

California/Berkeley, University of **A, B, C, D, E, F, G, H, I, J, K**
Civil Engineering Department
Berkeley, CA 94720
Contact: Prof. S.A. Mahin and Prof. A. Astaneh
Tel: (510) 642-4528 or 4081

California/Davis, University of **A, C, D, E, F, H, I, J, K**
Civil Engineering Department
Davis, CA 95616
Contact: Dr. I. M. Idriss
Tel: (916) 752-5403 FAX: (916) 758-1104

California/Irvine, University of **C, D, E, F, H, I, K, M**
Civil Engineering Department
University of California
Irvine, CA 92717
Contact: Dr. Medhat A. Haroun
Tel: (714) 856-5016 FAX: (714) 725-2117

California,/Los Angeles, University of **A, B, C, E, F, H**
Civil Engineering Department
Los Angeles, CA 90024
Contact: Dr. Lawrence G. Selna
Tel: (310) 825-5502 FAX: (310) 206-2222

California/San Diego, University of **A, B, C, E, H, I, J, K, M**
Department of AMES
La Jolla, CA 92093-0411
Contact: Dr. Frieder Seible
Tel: (619) 534-4640 FAX: (619) 534-6373

California/Santa Barbara, University of **A, B, F, H**
Department of Geological Sciences
Santa Barbara, CA 93106-9630
Contact: Dr. Ralph J. Archuleta
Tel: (805) 893-4477 FAX: (805) 893-2314

Carnegie-Mellon University **A, C, D, F, H**
Carnegie Institute of Technology
Department of Civil Engineering
Schenely Park
Pittsburgh, PA 15213-3890
Contact: Dr. Jacobo Bielak
Tel: (412) 268-2940 FAX: (412) 268-7813

Central Florida, University of **C, E, H**
Department of Civil Engineering and Environmental Science
Orlando, FL 32816
Contact: Dr. Sashi Kunnath
Tel: (407) 281-5770 FAX: (407) 823-3315

The Citadel **C, F, H, K**
Department of Civil Engineering
Letellier Hall, Room 207
Charleston, SC 29409
Contact: Dr. Charles Lindbergh
Tel: (803) 792-5083 FAX: (803) 792-7084

Colorado State University **L**
Hazards Assessment Laboratory
B250 Clark Building
Fort Collins, CO 80523
Contact: Mr. Dennis S. Mileti
Tel: (303) 491-7347 FAX: (303) 491-2191

Colorado, University of **C, D, E, F, H, I, L**
Department of Civil Engineering
Boulder, Colorado 80309
Contact: Dr. Hon-Yim Ko and Dr. Dan M. Frangopol
Tel: (303) 492-6716 or 7165 FAX: (303) 492-7317

Commerce, U. S. Department of
National Institute of Standards and Technology **A, C, D, E, F, I, J, K**
Building and Fire Research Laboratory
Center for Building Technology
Building 226, Room B168
Gaithersburg, MD 20899
Contact: Dr. Riley Chung
Tel: (301) 975-6069 FAX: (301) 869-6275

Cornell University **C, D, F, G, H, I, J**
School of Civil and Environmental Engineering
Hollister Hall
Ithaca, NY 14853-3501
Contact: Dr. Peter Gergely
Tel: (607) 255-4217 FAX: (607) 255-3760

Delaware, University of **L**
Disaster Research Center
Newark, Delaware 19716-2581
Contact: Dr. Joanne M. Nigg and Dr. E.L. Quarantelli
Tel: (302) 831-6618 FAX: (302) 831-2091

Drexel University **A, C, E, F, H, I, J, K**
Department of Civil and Architectural Engineering
Philadelphia, PA 19104
Contact: Dr. Harry G. Harris
Tel: (215) 895-2368 FAX: (215) 895-1363

Electric Power Research Institute **A, C, D, F, H, J, K**
Seismic Center
3412 Hillview Avenue
P.O. Box 10412
Palo Alto, CA 94303
Contact: Mr. J. Carl Stepp
Tel: (415) 855-2103 FAX: (415) 855-1026

Energy, U. S. Department of **A, B, C, D, F, H, I, J, K**
Natural Hazards Mitigation
EH-33
Washington, DC 20545
Contact: Mr. James R. Hill
Tel: (301) 903-4508 FAX: (301) 903-3888

U. S. Geological Survey **A, B, C, D, E**
345 Middlefield Rd., MS 977
Menlo Park, CA 94025
Contact: Dr. A. Gerald Brady
Tel: (415) 329-5664 FAX: (415) 329-5163

Georgia Institute of Technology **A, B, C, F, H, I**
School of Civil Engineering
Atlanta, GA 30332-0355
Contact: Dr. Barry J. Goodno
Tel: (404) 894-2201 FAX: (404) 894-2278

Idaho, University of **B, F**
Department of Civil Engineering
Moscow, ID 83843
Contact: Dr. Sunil Sharma
Tel: (208) 885-6403

Illinois, University of **C, E, F, H, I, M**
205 N. Mathews Ave.
Urbana, IL 61801
Contact: Dr. Mete Sozen and Dr. Douglas A. Foutch
Tel: (217) 333-3929 or 6359 FAX: (217) 333-9464

Johns Hopkins University **C, E, F, H, I, J, K**
Department of Civil Engineering
3400 N. Charles Street
Baltimore, MD 21218-2686
Contact: Dr. Nicholas P. Jones
Tel: (410) 516-8680 FAX: (410) 516-7473

Lehigh University **A, C, F, I**
Council on Tall Buildings
Fritz Engineering Laboratory
13 E. Packer Avenue
Bethlehem, PA 18015-3191
Contact: Dr. Lynn S. Beedle
Tel: (215) 758-3515 FAX: (215) 758-4522

Louisiana State University **C, E**
Department of Civil Engineering
3510 CEBA Building
Baton Rouge, LA 70803-6405
Contact: Dr. Luis A. de Bejar
Tel: (504) 388-8677 FAX: (504) 388-5990

Louisville, University of **C, H, K**
Center for Hazards Research and Policy Development
Department of Civil Engineering
Louisville, KY 40292
Contact: Dr. Michael A. Cassaro
Tel: (502) 588-6276 FAX: (502) 588-8851

Maine, University of **C, E, F, H, I**
Department of Mechanical Engineering
Orono, ME 04469
Contact: Dr. Vincent Caccese

Masonry Institute of America **C**
2550 Beverly Blvd.
Los Angeles, CA 90057-1085
Contact: Mr. James E. Amrhein
Tel: (213) 388-0472 FAX:(213) 389-7514

Massachusetts Institute of Technology **A, C, E, F, H**
Department of Civil and Environmental Engineering
Constructed Facilities Division, Rm. 1-353
Cambridge, MA 02139
Contact: Professor Eduardo Kausel
Tel: (617) 253-8437 FAX: (617) 253-6044

Memphis State University **A, B, C, E, F, H, I, K**
Center for Earthquake Research and Information (CERI)
3890 Central Avenue
Memphis, TN 38152
Contact: Dr. Tzyy-Shiou Chang
Tel: (901) 678-2007 FAX: (901) 323-2857

Michigan State University **E**
Civil & Environmental Engineering Department
East Lansing, MI 48824
Contact: Dr. Robert K. Wen
Tel: (517) 355-5109

Michigan, University of **C, F, H, I, K**
Department of Civil Engineering
2340 G. G. Brown Building
Ann Arbor, MI 48109-2125
Contact: Dr. Robert D. Hanson
Tel: (313) 764-5617 FAX: (313) 764-4292

Minnesota, University of **C, E, H, I, K, M**
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Missouri, University of **C, E, F, H, I, J**
Department of Civil Engineering
Rolla, MO 65401
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National Center for Earthquake Engineering Research **A, B, C, D, E, F, H, I, K, M**
State University of New York at Buffalo
Red Jacket Quadrangle
Buffalo, NY 14261-0025
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Nevada/Reno, University of **A, B, C, E, F, H, I**
Civil Engineering Department
Reno, NV 89557
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Nevada/Reno, University of **A, B, C, D, E, F, H, I, K**
MacKay School of Mines
Seismological Laboratory
Reno, NV 89557
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Tel: (702) 784-4265 FAX: (702) 784-1766

New Hampshire, University of **D, F, H, I**
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236 Kingsbury Hall
Durham, NH 03824
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New York/Buffalo, State University of **C, D, E, F, G, H, I, K, M**
Bonner Hall
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Northwestern University **A, C, E, F, H, I, K**
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Old Dominion University **C, F, H, I**
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Oregon State University **A, C, D, E, F, G, H, I**
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Pittsburg, University of **B, C, D, E, F, H, K**
Graduate School of Public and International Affairs, and
Civil Engineering Department
3E31 Forbes Quad
Pittsburgh, PA 15260
Contact: Dr. Louise Comfort and Dr. Fred Moses
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Princeton University **A, B, C, D, E, F, H, I, J**
Civil Engineering & Operations Research
School of Engineering and Applied Science
Princeton, NJ 08544
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Puerto Rico, University of **B, C, F, H, I**
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Rensselaer Polytechnic Institute **A, C, D, E, F, H, I**
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Troy, NY 12180
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Houston, TX 77251
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One Washington Square
San Jose, CA 95192-0080
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Southern California, University of **A, B, C, D, E, F, G, H, I, J, K**
School of Engineering
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Syracuse University **D, F, H, I**
L.C. Smith College of Engineering
Department of Civil and Environmental Engineering
220 Hinds Hall
Syracuse, NY 13244-1190
Contact: Dr. Shobha K. Bhatia
Tel: (315) 443-2311 FAX: (315) 443-1243

Texas, University of **C, E, F, H, I, J, K**
Ferguson Structural Engineering Lab
Balcones Research Center
10100 Burnet Road
Austin, TX 78758
Contact: Dr. James O. Jirsa
Tel: (512) 471-4582 FAX: (512) 471-1944

Transportation, U.S. Department of **E**
Federal Highway Administration (HNR-10)
Turner-Fairbank Highway Research Center
Structures Division
6300 Georgetown Pike
McLean, VA 22101-2296
Contact: Mr. James D. Cooper
Tel: (703) 285-2060 FAX: (703) 285-2766

Utah, University of **C, D, E, F, H, I, K**
Department of Civil Engineering
3220 Merrill Engineering Building
Salt Lake City, UT 84112
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Virginia Polytechnic Institute and State University **E, F, H, I, K**
Civil Engineering Department
Blacksburg, VA 24061
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Virginia Polytechnic Institute and State University **A**
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4044 Derring Hall
Blacksburg, VA 24061-0420
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Tel: (703) 231-6521 FAX: (703) 231-3386

Washington, University of **C, E, F, G, H, I**
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233 More Hall, FX-10
Seattle, WA 98195
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